New Horizons in Coatings and Thin Films
Room San Diego - Session F1

Nanomaterials and Nanofabrication

Moderators: Ulf Helmersson, Linköping University, Vitezslav Stranak, University of South Bohemia

1:50pm **F1-2 Kinetic Engineering of Crystal Phases in Core-shell Nanowires: Heteroepitaxial Radial Growth of Wurtzite and Zincblende Structured AlSb Shells on InAs Nanowires**, ***Hanna Kindlund***, *R Zamani, A Persson, S Lehmann, R Wallenberg, K Dick,* Lund University, Sweden

AlSb and InAs are III-V semiconductors belonging to the so-called 6.1 Å family, with room-temperature band-gaps of 1.61 and 0.36 eV, respectively. Their combination, especially to form low-dimensional heterostructures, is important to develop devices with potentially new applications based on the band-lineups that these heterostructures form. While zincblende (ZB) is the stable structure of conventional bulk III-V semiconductors, it has been shown that low dimensional structures such as nanowires can be grown in the wurtzite (WZ) crystal phase. Previous studies have also demonstrated the growth of nanowires composed of segments with both ZB and WZ crystal structures.[1-4]

Here, we use Au-seeded InAs nanowire core templates with engineered lengths of axial WZ and ZB segments and demonstrate selective, heteroepitaxial radial growth of AlSb on either ZB- or WZ-InAs nanowire segments. We grow InAs/AlSb/InAs core-double-shell nanowires on InAs(111)B substrates by metal-organic vapor phase epitaxy (MOVPE). The precursors used are trimethylindium (TMIn) and arsine (AsH_3) for the growth of InAs core templates, and tritertiarybutylaluminum (TTBAl) and trimethylantimony (TMSb) for AlSb. Using scanning electron microscopy, transmission electron microscopy, electron tomography, and energy-dispersive x-ray spectroscopy, we determine the AlSb shell thickness, crystal-phase, and nanostructure as a function of the shell growth temperature ($390 < T_s < 490$ °C).

We find that ZB and WZ structured AlSb shells grow epitaxially around the ZB and WZ segments of the InAs core, respectively. Interestingly, the WZ structured AlSb shells are thicker than the zincblende AlSb shells at $390 < T_s < 450$ °C with thickness increasing with decreasing growth temperature. In contrast, the ZB-AlSb shell thicknesses increase little with increasing T_s. In addition, detailed electron tomography studies show that the thicker WZ-AlSb shells form on the {11-20} facets rather than on the more commonly grown {1-100} sidewall facets. These results indicate that the growth of WZ-AlSb is preferred over the thermodynamically stable ZB-AlSb at lower growth temperatures. We attribute this behavior to kinetic limitations of MOVPE of AlSb on ZB and WZ phases of InAs.

References:

1. P. Caroff, K. A. Dick, J. Johansson, M. E. Messing, K. Deppert, and L. Samuelson, Nat. Nanotechnol. 4, 50 (2009)

2. K.A. Dick, C. Thelander, L. Samuelson, and P. Caroff, Nano Lett. 10, 3494 (2010)

3. S. Assali, L. Gagliano, D.S. Oliveira, M.A. Verheijen, S.R. Plissard, L.F. Feiner, and E.P.A.M. Bakkers, Nano Lett. 15, 8062 (2015).

4. S. Lehmann, J. Wallentin, D. Jacobsson, K. Deppert, and K.A. Dick, Nano Lett. 13, 4099 (2013)

2:10pm **F1-3 Understanding the Friction of Sub-nanometer Thick Ionic Liquids (Ils)**, *A Lertola,* ***Lei Li,*** University of Pittsburgh, USA

Ionic liquids show promise as lubricants for nano- and micro-electromechanical systems (NEMS/MEMS). When deposited on solid substrates as thin films, these liquids can exhibit solid-like layering structure, which makes them ideal as nano-lubricants. Moreover, Ionic liquids are “designer” materials with many possible molecular structures and tunable properties. In this work, we have investigated the friction of various nanometer-thick ionic liquids. While many previous studies showed the impact of cation, we found a dramatic difference in the friction coefficients for 1-Ethyl-3-methylimidazolium bis(trifluoromethylsulfonyl)imide (EMIIm) and 1-Ethyl-3-methylimidazolium tris(pentafluoroethyl) trifluoro phosphate (EMIM FAP), suggesting that anion structure also bears a significant effect on the friction. The effect of water at the interface has also been investigated and the friction profiles of the ionic liquids proved resistant to moisture manipulations. Film thickness, uniformity and adhesion to the substrate were also studied to relate molecular structure and surface morphology to tribology performance. The significance of these results in terms of Ils as potential MEMS lubricants will be discussed.

2:30pm **F1-4 Facile Synthesis of $MoSe_2$ Nanoplates on Black Phosphorus Nanosheets for Enhanced Hydrogen Evolution Reaction Performance**, ***Wan Li,*** City University of Hong Kong, Hong Kong*; D Liu, J Wang,* Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences, China*; M Huang,* City University of Hong Kong, Hong Kong*; N Yang,* Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences, China*; L Liu,* Peking University Shenzhen Graduate School, China*; X Peng, G Wang,* City University of Hong Kong, Hong Kong*; X Yu,* Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences, China*; P Chu,* City University of Hong Kong, Hong Kong

Today, seeking for cost-effective and efficient electrocatalyst is desired because hydrogen evolution reaction (HER) has been highly recognized as a promising approach to produce clean and renewable energy. $MoSe_2$ is an attractive candidate due to its fascinating properties. Unfortunately, aggregation as well as low conductivity restricts its developments. Here we report a smart strategy that $MoSe_2$ nanoflakes adhered on the surface of BP nanosheets through van der Waals interactions, aiming to increase conductivity and expose much more active sites simultaneously. It is found that the prepared $MoSe_2$-BP exhibits an enhanced electrocatalytic performance with a lower onset potential (200 mV), a smaller Tafel slope (109 mV dec^{-1}) and excellent stability. Such this performance can be attributed to the support provided by BP, which benefit efficient electrons transfer and prevent $MoSe_2$ from aggregating.

2:50pm **F1-5 Synthesis and Magnetic Properties of $Mn_xZn_yFe_{3-x-y}O_4$ Nanoparticles Prepared using a Co-precipitation Method**, ***Kuan-Wei Chen,*** *J Ting,* National Cheng Kung University, Taiwan

(Mn, Zn) ions were doped into Fe_3O_4 to form $Mn_xZn_yFe_{3-x-y}O_4$ nanoparticles for enhancing the magnetic property of. The $Mn_xZn_yFe_{3-x-y}O_4$ nanoparticles were synthesized through an easy, one-step, and quick aqueous co-precipitation method. Iron(III) chloride [$FeCl_3 \cdot 6H_2O$], manganese(II) chloride [$MnCl_2 \cdot 4H_2O$], and zinc chloride [$ZnCl_2$] were dissolved into hydrochloric acid to form the precursor solution. NH_4OH was then added into the precursor solution as reagent to the pH value. After vigorous agitation of the pH-adjusted precursor solution, precipitates were then collected. To investigate the microstructure, chemical composition, and magnetic properties, the obtained nanopowders were characterized using field emission scanning electron microscopy, Fourier transform infrared spectroscopy, X-ray diffractometry, electron Spectroscopy , and a superconducting quantum interference measurement device. The effects of Mn and Zn ion additions on the chemical composition and magnetic properties are presented and discussed. The and mechanism of $Mn_xZn_yFe_{3-x-y}O_4$ nanoparticle formation is also discussed.

3:10pm **F1-6 Effects of Nano Particles on the Thermal Stability and Scratch Resistances of Epoxy Coatings**, ***Mourad Boumaza,*** *K Rawaiz,* King Saud University, Saudi Arabia

Coatings are susceptible to damage caused by scratch and/or abrasion and thermal instability. Clearly, the consumer prefers to retain the aesthetic appearance of coated materials and for this reason clear coats used on automobiles must have good scratch and abrasion resistance. An added problem is that scratches may also cause damage to the underlying substrate. Scratch resistance can be obtained by incorporating a greater number of cross links in the coating's binder but unfortunately highly cross linked (hard) films have poor impact resistance due to less flexibility. A less cross linked (softer) film will show better performance with regard to other properties such as anti-finger print and impact resistance but will have less scratch and abrasion resistance

On the other hand thermal performance of materials is crucial in many industries, ranging from pharmacy, battery and aerospace and electronics tod construction industries. For optimum thermal stability, heat dissipation, bonding and homogeneity are key parameters of thermal characterization and thermal conductivity, Many researchers recently worked on thermal stability of epoxy/nanoparticles coatings by using different types of nanoparticles

The purpose of this work is to investigate the effect of inorganic nanoparticles on scratch resistance and thermal properties of epoxy/Polyamid coating system. The nano composite coatings are formulated by incorporation of various types of nanoparticles (ZrO_2, ZnO, SiO_2, and Fe_2O_3) with 2 wt. % loading for each type of nanostructure.

The results showed that all the composite coatings with 2% loadings of Nanoparticles increased and passed the impact test of 120 lbs/in as compared to the unreinforced coating which cracks at 112 lbs/in. However the impact value for EPZN remains the highest and showed 57% increase in the impact resistance. Similarly the Scratch resistance for all the samples increased in all compositions, while EPSI was found to have highest Scratch load. The increasing trend in the scratch hardness values can be attributed to the improvement in the adhesion between composite coating and metal substrate.

Thermal analysis of these nano composites revealed that the addition of SiO_2 and ZrO_2 enhanced the thermal stability of the nano composite coating, while Fe_2O_3 and ZnO reduce the thermal stability due to catalytic effect of these nanoparticles, which facilitate the thermal degradation process.

3:30pm **F1-7 Corrosion Study of Silane-functionalized Graphene Oxide Coatings on Copper***, **Mohsin Ali Raza**, Z Rehman, F Ghauri,* University of the Punjab, Lahore, Pakistan

This research work aims to produce corrosion resistant silane-functionalized graphene oxide (GO) coatings on copper (Cu) metal. Two types of precursor graphite (flakes and powder) were utilized to synthesize GO following improved Hummers' method, and resulting GO was labelled as FGO and PGO, respectively. GO was deposited on copper metal, which was made anode and platinum was made cathode, from GO/water suspension by electrophoretic deposition (EPD). Silane functionalization was performed by immersing GO-coated samples in 3-aminopropyltriethoxy silane (APTES) solution. The role of precursor graphite, deposition time, surface roughness of substrate, and post-treatment of GO coating with silane on corrosion protection ability of GO coatings was studied. Characterization of GO and silane-functionalized GO coatings was performed by X-Ray diffraction, atomic force microscopy, Fourier transform infrared spectroscopy and scanning electron microscopy. Optimum EPD parameters for the development of uniform coatings were found to be 5 V and 30 sec with GO/water concentration of 1:10. Corrosion behavior of GO and silane-functioanlized GO samples was studied by Tafel analysis, electrochemical impedance spectroscopy (EIS) and cyclic voltammetry (CV) in 3.5 % NaCl solution. The results showed that precursor graphite effects quality of GO, and consequently the corrosion behavior of the GO coatings. PGO-coated Cu deposited at optimized parameters showed better corrosion protection compared to FGO-coated Cu. Tafel analysis showed that PGO coating and silane-functionalized PGO coating developed at optimized parameters enhanced corrosion resistance of Cu by ca. 6× and 25×, respectively, compared to bare Cu. Tafel results were well validated by EIS and CV.

3:50pm **F1-8 Growth of MnO_2 on Carbon Materials for Electrochemical Capacitor***, **Chia-Jung Tu**, M Wu,* National Changhua University of Education, Taiwan*; W Wu,* Da-Yeh University, Taiwan

Manganese oxide (MnO_2) has attracted intensive attention and been widely used as catalysis, ion exchange, molecular adsorption, biosensor, and electrodes for lithium ion batteries and supercapacitors due to its low cost, abundance and environmental-friendliness. For supercapacitors, MnO_2 is the most investigated oxide for pseudocapacitors on the basis of its high theoretical specific capacitance of 1370 Fg^{-1}. However, the theoretical specific capacitance of MnO_2 has rarely been achieved due to its poor electrical conductivity. Therefore, a hybrid electrode architecture which incorporates nanostructured MnO_2 on high-surface-area conductive carbon materials was used to improve the electrical conductivity and the specific capacitances. In this study, activated carbon fiber cloth (CFC) and vapor grown carbon nanofiber (VGCNF) was used as the carbon support material. The pretreatment condition of the vapor grown carbon nanofiber were first discussed. Then, nanostructured MnO_2 was grown on activated carbon fiber cloth and vapor grown carbon nanofiber using three different wet chemical methods and conditions. It was observed that different concentration of the precursor $KMnO_4$ play a crucial role in the crystal growth of MnO_2, which result in different morphology.

4:10pm **F1-9 Fabrication of a CMOS Compatible Ferroelectric Tunnel Junction Memory***, **Fabian Ambriz-Vargas**,* Énergie, Matériaux et Télécommunications, Canada*; G Kolhatkar,* Institut National De La Recherche Scientifique, Canada*; R Nouar, A Sarkissian,* PLASMIONIQUE Inc, Canada*; M Gauthier, A Ruediger,* Institut National De La Recherche Scientifique, Canada

Semiconductor memories are the key component of any electronic device. Among the different types of semiconductor memories, Dynamic Random Access Memory (DRAM) is the most used memory in the semiconductor market. However, the continue miniaturization of the electronic devices leaded to reach the DRAM physical limits. Then, new types of semiconductor memories based on different physical approaches are now attracting attention. One candidate to replace DRAM technology is the Ferroelectric Tunnel Junction memory (FTJ), which offers advantages such as a low operating energy, high operation speed (read/write access; ~10ns/10ns), high endurance (10^6 cycles) and non-volatility.

Recently, it was reported the successful fabrication of the first FTJ devices. They were based on perovskite tunnel barriers such as barium titanate ($BaTiO_3$), bismuth ferrite ($BiFeO_3$), lead titanate ($PbTiO_3$) etcetera. However, FTJs based on perovskite tunnel barriers require of specific substrates (strontium titanate, $SrTiO_3$) and high processing temperatures (~700ºC) which makes them incompatible with the complementary metal oxide semiconductor process (CMOS). In comparation to perovskites, Hafnium-Zirconium oxide ($Hf_{0.5}Zr_{0.5}O_2$) films offer advantages such as CMOS compatibility as well as ferroelectric properties in ultrathin form.

Thus, in the present work, we report on the fabrication of the first FTJ memory device based on a CMOS compatible tunnel barrier $Hf_{0.5}Zr_{0.5}O_2$ (6 unit cells thick, ~3nm thick film) on an equally CMOS compatible TiN electrode. Such a device will give rise to a new generation of semiconductor memory devices.

4:30pm **F1-10 Polyacrylonitrile Nanofibers Prepared via Electrospinning for High-efficiency PM2.5 Capture Application***, **Kuan-Nien (G.N.) Chen**,* Unaffiliated*; J Ting,* National Cheng Kung University, Taiwan

TiO_2 surface-residing electrospun PAN nanofibers with controllable density of TiO_2 on the fiber surface were prepared by means of an electrospinning technique and microwave hygrothermal method. The nanofiber diameter was controlled by the voltage, precursor viscosity, and flow rate during the electrospinning process. The surface morphology was controlled by adding TiO_2 with different concentrations. The surface chemistry was optimized to enhance PM adsorption. SEM, TEM and XRD pattern analyses demonstrated that TiO_2 was formed and resided on the nanofiber surface, and surface chemical composition was analyzed by XPS. Selected samples were evaluated for filtering efficiency by examining the particle counter (CEM) and the removal efficiency was calculated by comparing the PM particle number concentration before and after filtration.

Author Index

Bold page numbers indicate presenter